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DETERMINATION OF THE CUMULUS SIZE DISTRIBUTION
FROM LANDSAT PICTURES

E. Karg, H. Müller, and H. Quenzel

Translation of "Bestimmung der Cumulus-
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16. Abstract Varying isolation causes undesirable thermic stress to the receiver of a solar tower plant. The rapid change of isolation depends on the size distribution of the clouds; in order to measure these changes, it is suitable to determine typical cumulus size distributions. For this purpose, LANDSAT-images are adequate. Several examples of cumulus size distributions will be presented and their effects on the operation of a solar tower plant will be discussed.			
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DETERMINATION OF THE CUMULUS SIZE DISTRIBUTION FROM LANDSAT PICTURES

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1142 *

1. Introduction

A solar tower power station converts direct solar radiation into heat which is used finally with the ordinary technology to generate electricity. The direct solar radiation occurring is deflected by mirrors to a receiver on a turret; from there a suitable medium removes the heat arising.

The temperature in the receiver depends on the intensity of its irradiation and therefore also on the effectively irradiated mirror surface. If clouds shade temporarily the mirror field, the alternating energy supply induces temperature fluctuations difficult to estimate in the receiver which stress its material very strongly and prevent a stationary operation of the plant.

From a study of the Meteorological Institute of Munich (Mueller et al, 1981, pages 32-34) the following parameters are obtained which affect the power reaching the receiver;

--the direction from which the cloudiness comes causes "unbalanced loads" since the mirror field is not arranged concentrically around the tower;

--the speed with which the clouds move over the area determine how quickly the radiation penetrations occur; increasing degree of cover reduces the total radiation capacity, but also reduces its relative variations;

*Numbers in the margin indicate pagination of foreign text.

--the cloud size modulates greatly the relative fluctuation of the radiation power.

The estimated component, more exactly the ratio of the area of the cloud shade to the area of the mirror field shows what clouds must be referred to as "large" or "small" with reference to the power station. According to the estimate of Mueller et al (1981, page 35) clouds of a few hundred meters diameters must already be included among the "large" ones. Since the insolation level on the receiver is the integral /143 over the contributions of the individual mirrors to the heliostatic field, this means that many "small" clouds compensate each other, while individual "large" ones have an intense effect. But the amount of shade is very different particularly for broken clouds. Therefore it is suitable to study the sizes of individual clouds. Both the publication cited below which examines the problems of cloud size distribution apply to regions of the U.S. The experiment of applying the results obtained there to the site of our power station will only be reliable if comparable control measurements are available.

2. Procedure for Determining the Cloud Size

The measurement from the satellite was preferred to methods involving aircraft or the ground, since it offers the advantage that system-induced errors can be corrected and measurement data are available. For other methods the data would have to be obtained further by measurements on the site to be carried out specially. Since the resolution of less than 100 m is needed to identify the critical cloud sizes for the power station in question only the Landsat system can be used. Allowances must be made for the drawback that an observation may be obtained only every ninth or eighteenth day.

The 0.6-0.7 μm channel of the multispectral scanner shows a good contrast between the earth surface and clouds, but still allows sufficient differentiation of the ground

as well as the identification of water surfaces. A difference between clouds or snow or sand can naturally be made only by visual patent recognition in this spectral range. To be able to obtain a preliminary selection in the cases to be processed photographic products are chosen as data carriers.

In the evaluation each time an image is scanned with an optical system of analysis and stored. With a computer it is possible then to carry out manipulations on the screen: the clouds are identified by interaction with progressive contrast amplification and the prerequisites are obtained for the subsequent mechanical identification and differentiation of the individual clouds. The number of the image elements corresponding to a cloud is a measure of the area of the cloud, the total number of the image elements identified as clouds represents a measure for the cloud amount.

3. Characteristics of the Cloud Size Distribution

The basis for the study includes 29 Landsat pictures which were taken from 1975 to 1977 over southern Spain, which were processed by the above-indicated method.

With a known image scale the actual area of the clouds is calculated. The diameter of a circular area equivalent to the corresponding cloud area allows the comparison with the results of other authors.

According to the equivalent diameter the clouds are divided into classes, a histogram regarding the frequency of occurrence of these classes is established and the contribution of these cloud size classes to the total cloud cover obtained.

It was found that the smallest equivalent diameters occurring are limited by the resolution of the satellite; a comparison with a study by Plank (1969, page 52) shows that clouds up to the range of a few decameters size exist. The maximum diameters of several kilometers are determined first by the extent of cluster formation, but then depending on the site, time of year or day and weather situation in a manner which cannot be quantized in greater detail.

The number of clouds occurring per size class decreases basically with the in- /144
creasing diameter. This diameter is connected strongly with the time of day. Plank
(1969, page 56) shows it to be strong in the morning, weaker around noon and once
again increasing in the evening. Since the Landsat pictures are taken always at
about 11 o'clock local time, they do not allow any extrapolation to the course of
the day. The connection of the decrease in different geographical sites is not clear
in the publications by Gifford and McKee (1977, pages 17-35). The relationship studied
by us with the seasons seems to be difficult to quantize.

If the frequency of clouds is plotted logarithmically over the size classes, we
obtain a more or less linear relationship with the size class. Plank (1969, pages 60
and following) represented therefore the cloud size distribution by an exponential
law. This improves the possibility of comparing the studied cases and describes the
size distribution in a suitable form, but does not explain any physical backgrounds.

4. Consequences for the Power Station

With regard to the size ratio between cloud and mirror field the consequence of
a reduction of the field is that the power station must be shut off even for small
cumulus cloud cover (or in the appearance of the smallest cloud of the size distri-
bution). The larger the mirror field, the less sensitive the plant will be to broken
clouds.

The reactions of a power station of about 0.2 km^2 mirror area on cumuli of 30 m
to 1 km diameter were estimated by Mueller et al (1981, page 33). Clouds with diameters
less than 1 km are included among the small clouds in the cloud size spectrum; they are
however already "large" for the above power station dimensions and therefore cause
surprisingly strong inroads in the insolation level.

5. Literature

Mueller, H. et al. Study of the Insolation Analysis within the Framework of the GAST Project. Meteorological Institute of the Munich University (1981).

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